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NATIONAL PARK SERVICE
Water Resources Division - PEB
P.O. Box 25287
Denver, CO 80225

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Memorandum

To: Alexa Roberts, Super-Superintendent, Sand Creek Massacre National Historic Site

Through: Dean Tucker, Acting Chief, Planning and Evaluation Branch, Water Resources Division (WRD)

From: Mike Martin, Hydrologist (WRD), Kevin Noon, PhD, Wetland Scientist (WRD)

Subject: Travel Report. Geomorphic assessment of Big Sandy Creek, Sand Creek Massacre National Historic Site (SAND) May 18-20, 2011

Purpose

The primary purpose of the trip was to define the relationship between natural resources (specifically geomorphic landforms and riparian vegetation) and the approximate historic position of the active channel of Big Sandy Creek by assessing the possibility of substantial channel migration and/or avulsion since 1864. A second purpose (related to ongoing hydrologic investigations) was to install continuous water-level recorders in six of the existing shallow-groundwater wells. The recorders will allow park staff to monitor ground water fluctuations electronically over several years without having to dedicate resources to visit each well on a bi-weekly schedule. These data will be used to determine the long-term trend of water table elevations in the alluvial aquifer associated with Big Sandy Creek.

Figure 1 - Standing on the man-made levee (at the mouth of the Chivington Canal) across from one hypothesized encampment location

Problem Statement

A concentration of artifacts was found about 0.6 mile north of the existing Dawson Bend (please see figure 2). The location of the artifacts was hypothesized to be an alternative location of the tribal encampment. Some of the historic data suggest that the encampment was close to a bend in the active channel. If the concentration of artifacts represents the location of the encampment, then the active channel bend in 1864, as described in the historic accounts, may have been located more than 0.5 mile further north of its current location. The problem is to determine if there is geomorphic evidence indicating that there was an active channel alignment roughly 0.5 to 0.8 mile north of its current location at Dawson Bend in the mid 1800's.

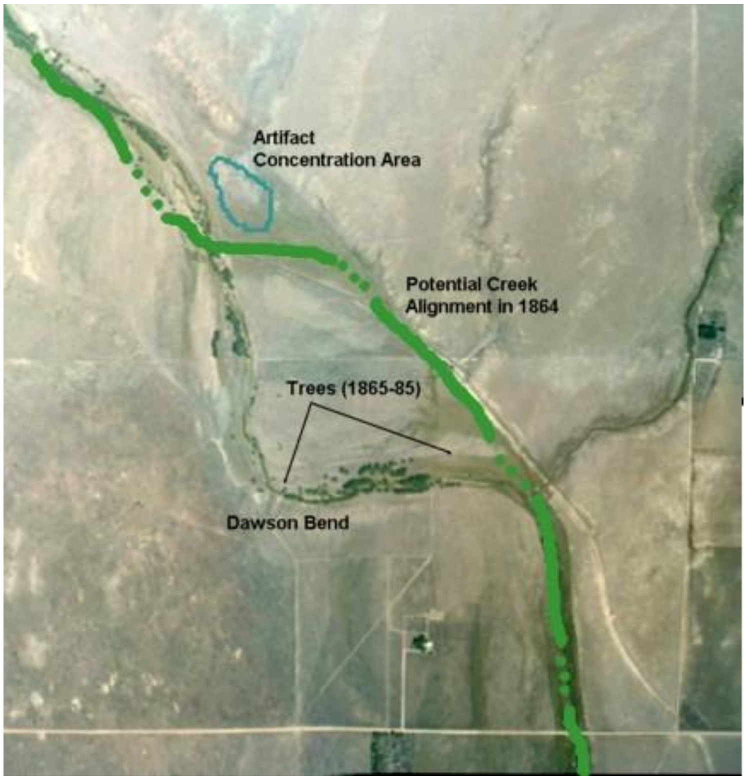

Figure 2 – Aerial photograph of the study site with the present day channel and a potential former channel alignment (green)

Summary

A detailed geomorphic assessment of the entire drainage within the park was beyond the scope of this field exercise, therefore, these conclusions are preliminary. However, in the areas we were able to evaluate we did not identify any features that suggest the active channel of Big Sandy Creek has been in any dramatically different alignment throughout the past several hundred years. This preliminary conclusion is based on the position and ages of riparian cottonwood galleries and the prehistoric fluvial terraces that are present throughout the valley. We did not locate any creek channel features either superimposed on, or truncating through, the old terrace formations. Based on these field observations, we have to preliminarily conclude that the active channel of Big Sandy Creek has been within the modern floodplain throughout recorded history. However, a thorough examination of the area needs to be completed before we can conclude that no other modern channel features are present anywhere besides within the modern floodplain.

Discussion

A meeting was held at the park and attended by tribal members, tribal representatives, park staff, cooperators from Utah State University, and NPS Water Resources Division and Intermountain Region GIS staff. The purpose of the meeting was to review evidence and theories of where the Native American encampment was located at the time the massacre took place. At the meeting we reviewed historical maps, oral history accounts, and written documents, and then examined remotely sensed data (aerial photos and satellite imagery) of the physical conditions around the hypothesized encampment sites. Additionally, we evaluated the conclusions from two previous studies conducted in SAND, one that determined the age class and structure of the riparian vegetation (Lukas and Woodhouse, 2006) and one that identified and preliminarily determined age of fluvial terraces (Holmes and Mcfaul, 1999).

Oral histories and two hand drawn maps by George Bent (present at the time of the massacre) stressed that the encampment was located inside a “bend” in the river. There is currently a prominent bend, Dawson Bend, in the river on the park site. Several other historical maps do not depict the channel in its present day alignment, including: Bent County School Map, GLO maps from 1879-1880, and USGS topographic maps from 1891 to 1892. Of particular interest is a 1904 State Engineers map of ditches and reservoirs in Water District 67, which specifically does not depict the modern day Dawson Bend. This information calls into question the location of the Big Sandy Creek active channel over the last 150 years.

The NPS found a concentration of artifacts in an area on the northern edge of the Dawson Bend floodplain which they interpreted to be the encampment area (please see figure 2 above). However, the tribes determined the George Bent map to be of greater evidence that shows the layout of the camp within a bend that looks very much like the current Dawson Bend. Therefore, the tribes and the NPS were 0.6 mile apart in their interpretations of where the camp was located. The enormously important thing here is that if the camp was where the artifacts were found, if the current Dawson Bend wasn’t there in 1864, and if the bend was further north on the west side of the artifact area (as shown in Figure 2), then it means that the artifacts do indicate the camp location relative to George Bent’s map that shows the camp within a creek bend. Therefore, determining the location or configuration of the 1864 channel, using geomorphological data, could be important to defining the encampment location. Knowing the position of the encampment is also important to developing interpretive programs and media and to the development of an accurate General Management Plan.

In order to explain the location of the potential creek alignment in 1864, it was posited that the construction of the Chivington canal in about 1913 and other land use activities, primarily agriculture practices, may have altered the location of the creek bend to its current location, and/or obliterated any traces of a former channel.

To provide adequate background for a geomorphic assessment, this document presents a summary of geologic, hydrologic, botanical, and soils information for the overall watershed and the Historic Site in particular. Our objective was to evaluate physical evidence (including the geomorphology and dendrology data) and provide our best estimate of where the river bend was located, or more precisely, where it could not have been relative to its present location, at the time of the massacre. Our objective was not to dispute the camp location theories or the evidence that supported the theories. Nor did we dispute the presented evidence for the location of the channel bend that was proposed to be outside the existing active creek channel.

Data Review

The configuration and location of a stream channel and its associated floodplain can be influenced by a combination of local geology, climatic history, and, in some places, human manipulation. Consequently, understanding geologic, hydrologic, and climatic controls as well as human influence is crucial to landscape interpretation. With that in mind, we provide a fairly detailed description of the local geology and hydrology with particular emphasis on recent geomorphic history. Additionally, we also include botanical and soils information where it is relevant to the question of stream morphology. A complete review of known and proposed human manipulation is beyond the scope of this assessment, however, this potential influence was continually considered.

Geology and Hydrology

The entire Big Sandy Creek drainage basin is about 3,400 square miles beginning in the vicinity of Limon, Colorado and continuing predominantly southeast until forming a confluence with the Arkansas River about eight miles east of Lamar, Colorado. The major tributaries of Big Sandy Creek are Rush, Wild Horse, and Big Spring Creeks, the largest being Rush Creek. The site of the Sand Creek Massacre is along the lower reaches of the creek several miles above the confluence with Rush Creek. The Sand Creek Massacre National Historic Site itself encompasses about seven miles of the creek.

As the name implies, Big Sandy Creek, also known as Sand Creek, is an alluvial stream, meaning that its bed and banks are composed of sediment recently transported (in a geologic sense) by the watercourse. The valley that Sand Creek occupies has been carved out of Cretaceous bedrock formations, namely the Pierre Shale, the Niobrara formation, and the Carlile Shale. These predominantly marine deposits are very thick (upwards of 4000 feet) and are also relatively impermeable. Consequently, the bedrock formations underlying the valley-fill alluvium serve as confining layers, prohibiting downward movement of soil water and groundwater, and encouraging water table conditions in the overlying Quaternary sediments. With that, the unconsolidated sediments overlying the Cretaceous bedrock serve as the major water-bearing formations (aquifers) in the area (Coffin and Horr, 1967). The next stratigraphically lowest formation that may serve as a dependable aquifer is the Dakota Sandstone, which lies at a minimum of about 2000 feet below the Pierre Shale in this area. Given the depth of this aquifer, its water is probably highly mineralized and non-potable.

As mentioned, it is the Quaternary sediments in this area that serve as the only reliable aquifers. These sediments range in composition from gravel, sand, and silt to clay and were deposited both by flowing water (alluvium) and wind (eolian). The material itself is re-worked Pliocene and Pleistocene deposits with a small portion coming from the Cretaceous bedrock. Three broad categories of Quaternary deposits are present in the area: upland deposits, valley fill deposits and eolian deposits, with the valley fill and eolian deposits being of primary interest to this assessment.

The upland deposits occur on the rolling highlands that border Sand Creek valley and vary in thickness from 0 to about 40 feet. They overlay a relatively smooth surface of eroded Cretaceous bedrock that slopes southward at about 20 feet per mile (0.4%). The surface of the upland Quaternary deposits also slopes uniformly to the south and sits topographically higher than the valley that contains Big Sandy Creek. Despite the fact that the upland deposits are relatively permeable and receive substantial precipitation, they generally do not form reliable aquifers because their topographic position results in them being well drained (Coffin and Horr, 1967). Additionally, numerous ephemeral drainages dissect the upland deposits providing flow conduits to the topographically lower valley fill deposits. Some low-yield stock and domestic wells have been finished in the upland deposits, but they are generally associated with closed depressions in the bedrock. The springflow that enters the park near the southeast boundary likely emanates from this upland deposit and then flows through valley-fill alluvium in the tributary drainage before reaching the main valley-fill deposits associated with Big Sandy Creek.

The valley-fill deposits, which include both the tributaries and the main-stem drainages, occupy channels carved out of the Cretaceous bedrock and in some places, older Quaternary deposits. The valley-fill along Big Sandy Creek is composed of different particle sizes ranging from gravel to clay with an average thickness of about 25 – 30 feet. The range of thickness varies from 0 to about 70 feet with the areas of thickest deposition in the approximate center of the valleys.

Geomorphic History

The overall configuration of the creek is a meandering alluvial channel underfit in its broad valley. Competent flows, those capable of transporting sediment and re-working the channel, are rare and occur roughly about every four years or so. As a result of this infrequency of “channel forming flows” Big Sandy Creek channel was poorly defined at the time of the site visit. The geomorphic features that are generally associated with meandering streams (such as point bars, cutbanks, and overflow channels, to name a few) are largely absent or poorly formed. Quaternary fluvial terraces, however, are both well formed and well preserved, throughout the area.

Meandering streams, as their name implies, have a tendency to migrate over the landscape changing the alignment of the active channel through time. Generally, there are two mechanisms for channel shifting; continual lateral migration in response to normal flows and episodic shifts that generally result from extreme events. Either one of these processes leaves diagnostic geomorphic landforms. More specifically, continual lateral migration will remove older terrace deposits forming a continuous modern floodplain at a relatively lower elevation. Channel avulsions may preserve some older terrace deposits but leave behind remnants of abandoned channels.

The valley that contains Big Sandy Creek is fairly broad measuring greater than 3000 feet width in the vicinity of the Historic Site, with the Cretaceous bedrock forming rolling highlands on either side of the valley. Varying thicknesses of alluvial material (valley fill) are present within the valley and these different thicknesses roughly correspond to age classes of the landforms. At least four

fluvial terraces as well as the modern floodplain have formed in the valley fill deposits along Big Sandy Creek, with the three youngest terraces occupying distinct elevations within the valley (Coffin and Horr, 1967). A focused study aimed at identifying likely locations of in-situ cultural material in the vicinity of SAND indentified the presence of these three terrace levels (in addition to the modern floodplain level) throughout the Historic Site (Holmes and Mcfaul, 1999).
At this time, the landforms within the valley have not been mapped or dated in great detail, however, soil analyses conducted by LaRamie Soils Service between 1998 and 1999 provide preliminary data regarding landform position, approximate age (both absolute and relative) and degree of recent disturbance, both natural and anthropogenic (Holmes and Mcfaul, 1999). This study resulted in the collection of 64 soil cores from four separate locations along Big Sandy Creek. The area most heavily sampled was near the Dawson Bend where 27 cores were collected.

The remaining 37 cores were collected at three sites farther north along the drainage. One site of particular interest was located near the inlet to Chivington Canal; this site yielded two radiocarbon dates from paleosols in two different fluvial terraces. The four main landforms that were included in this study were: the modern floodplain (T0), the lowest terrace (T1), an intermediate terrace (T2), and the highest elevation terrace (T3) within the valley. Additionally, one soil core was collected from the upland level.

The floodplain level (T0) lies at about the same elevation as the modern stream channel and is fairly smooth with some evidence of modern channel features. The width of the active floodplain varies from about 150 to less than 300 yards and is bounded by fluvial terraces of different ages or bedrock cliffs at some locations. Very weak soil development on the surface of the floodplain level implies a very young landform consistent with a floodplain and active stream channel system. Any cultural material found on this landform would likely have been reworked by fluvial action.

Terrace level one (T1) is the next oldest Landform. It is adjacent to the modern floodplain, at least where it has not been removed by erosion. The surface of this terrace level is about 1.5 feet above the floodplain level. The alluvial material is predominantly coarse grained sand but may be covered with as much as 10 cm of medium grained, well sorted, eolian sands. This mantle of wind derived sediment is discontinuous, variable in thickness, and may obscure boundaries between older landforms. The modern soil on the surface of T1 (both the alluvium and the eolian deposits) is weak to moderately developed suggesting a greater time for soil formation than the floodplain level. Furthermore, at least two buried paleosols with complex structure identified in this landform imply periods of subaerial exposure and subsequent aggradations. Lastly, a soil core collected just north of the Chivington Canal inlet yielded a radiocarbon date of 1030+/- 70 yr BP. This sample was extracted from soil humates in a paleosol buried at 23 cm below the surface. Consequently, this landform (T1) appears to be at least about 1000 years old representing a floodplain that was active well before Anglo occupation of the Western United States.

The intermediate terrace (T2) is approximately three feet above the floodplain level. It is predominantly coarse to very coarse grained, poorly sorted sand. Similar to T1, this terrace level is covered by a discontinuous layer of well sorted eolian sands. However, the eolian deposits are both thicker and somewhat coarser on T2 than T1. This discontinuous, wind-derived deposit ranges in thickness from 0 to 60 cm with particle sizes ranging from medium to coarse. This landform contains at least one buried paleosol and yielded a radiocarbon age of 2390 +/- 110 yr BP. This age was derived from soil humates in a paleosol buried at about 97 cm below the surface near the Chivington Canal inlet. Consequently, the T2 terrace likely formed about 2000 years ago as a floodplain and active channel.

The oldest terrace (T3) is generally on the outer margins of the valley and sits at a higher elevation than either T1 or T2. Like the other two lower terraces, T3 is capped by a discontinuous, eolian sand deposit of varying thickness. In fact, there are two distinct eolian deposits at some locations separated by a well formed paleosol and the total depth of this wind-derived sand may exceed three feet or more.

Complicating the general “stairstep” configuration of the fluvial terraces is the presence of a varying depth of eolian sand throughout the site, and areas where the terraces have been dissected by tributary flows. Additionally, agricultural practices may have re-worked the surface topography in places altering the terrace configuration. Surface disturbance (both natural and anthropogenic) was one of the soil conditions assessed by Holmes and Mcfaul, but they only collected one sample with an identifiable plow-zone. Also, during our short reconnaissance of the area we identified areas of obvious surface disturbance (Figure 1) and extensive, well formed and well preserved fluvial terraces in some locations (Figure 3). Careful topographic mapping and grain size analyses of the near surface soils should yield a fairly detailed configuration of the different terrace levels within the site. This is significant information because any location where an intact terrace (T1, T2 or T3) exists is also a location where the active channel of the river could not have been in 1864.

Figure 3 - Looking north along the east side of Big Sandy Creek channel between Dawson Bend and the inlet to the Chivington Canal. Note the low area on the left with Cottonwoods (modern floodplain), the poorly defined channel in the middle (T0), and the higher terrace on the right with sage brush (presumed to be T1). The sagebrush covered terrace is continuous in the northern direction for about 1500 feet; it is very well formed and very well preserved with no evidence of former abandoned channels.

Fluvial terraces may form by deposition, erosion, or a combination of both. Given our state of information, it appears that the terrace sequence present today is a result of at least three major episodes of channel incision and widening, with intermediate periods of aggradation. The grain size distribution within the valley fill deposits, specifically, a fining upward sequence observed in test holes and a general down valley fining throughout the watershed suggest that the valley fill was deposited as a unit (Coffin and Horr, 1967). Therefore the highest terrace level (T3) may represent the original deposition surface. Subsequently, episodes of downcutting and widening occurred forming a floodplain level below the original deposition surface. Three of these downcutting and widening events produced the landforms we see today, two associated with T2 and T1 and one associated with T0, the modern floodplain. Based on the small number of absolute dates derived from paleosols in the T1 and T2 terrace levels, the first episode of downcutting occurred about 2000 to 2500 years ago and the second about 1000 years ago. The final episode occurred sometime after that time – producing the landscape we see today. For this immediate time period, Big Sandy Creek appears to be in a period of aggradation as is evinced by a general lack of an active channel.

Flow Conditions on Big Sandy Creek

The Big Sandy Creek Basin is located in a semi-arid portion of the country where annual evaporation greatly exceeds annual precipitation. Big Sandy Creek generally flows only in response to substantial rainfall events; however, there are a few reaches that support perennial flow due to higher water table conditions. One such reach is within the Historic Site near the downstream end where spring flow from the east helps to maintain a higher water table and perennial surface water. The rest of Big Sandy Creek within the Historic Site is an ephemeral watercourse, and due to very infrequent flows, has a poorly defined channel through most of its length.

Several miles downstream from the Historic Site, the USGS has operated a gage on a perennial reach of the stream for 30 years, 1968 to 2010 with a number of missing years from 1983 -1995. The range of annual peak flows recorded by this gage at Lamar (#07134100) are generally from about 100 to 500 cubic feet per second (CFS), with an occasional peak around 500-600 CFS. Two recorded peaks from the 30-year record exceeded 2000 CFS. On the other end of the flow distribution, daily discharge minimums have generally been below 10 CFS throughout most of the record, and even daily mean maximums are usually below 100 CFS. These relatively low flow values are generated from a contributing area that exceeds 2000 square miles suggesting that this watershed is relatively inactive. This is not to say that large flow events do not occur - they are relatively rare and short lived. More importantly, regular channel forming flows, those most responsible for channel migration, are also relatively rare.

One of the reasons for the paucity of channel forming flows in this reach of Big Sandy Creek is the geology of the greater watershed. Throughout the entire watershed, the width of the floodplain as well as the active channel, where present, decreases in the downstream direction. This is contrary to a more typical watershed where the volume of flow and associated channel and floodlain width generally increase farther down the drainage. In the case of Sand Creek watershed, the downstream narrowing of the channel and floodplain is attributed to continual loss of runoff volume to the groundwater system through percolation. One of the geomorphic results of this condition is that the

Big Sandy Creek is relatively inactive compared to a stream that experiences a bankfull event every year or two. Channel migration will still occur in this system; however, it will be much slower than a meandering stream with regular channel forming flows.

The present flow regime in Big Sandy Creek is strongly dependent on the prevailing climate. Simple observation of the greater geomorphology tells us that the Big Sandy Creek of today is a much different system than the one that carved out the broad valley and formed the fluvial terraces. With that, the question of recent climate shift and the nature of Big Sandy Creek over the last couple hundred years must be addressed.

One of the proxy indicators that we may use in assessing the nature of the creek in recent history is the age class and structure of the mature cottonwood galleries present along the watercourse. In 2005, Lukas and Woodhouse from the institute of Arctic and Alpine Research in Boulder, Colorado conducted a detailed sampling of the riparian galleries within the park. In brief, the researchers identified three age classes along the drainage. The oldest class had an estimated germination date range of 1865 – 1885 (located in Figure 2). There were no individual trees sampled that unequivocally were alive at the time of the Massacre, but, considering the associated error with the age determination, the researches believed that some of the oldest present trees were likely saplings in 1864. The two other age cases identified were 1908 – 1925 and 1949-1960. There has been little to no cottonwood establishment since 1960.

Also of interest to this assessment is the distribution of these age classes. Almost all of the cottonwoods present in the drainage were within 200 yards of the active channel and the vast majority was within 100 yards. The most recent age class, 1949 – 1960, was predominantly associated with the active channel. The two older classes were located farther from the channel but still along the same general alignment. This arrangement suggests that the active channel of Big Sandy Creek has undergone some degree of migration since 1865, but the present alignment is basically the same as it was 150 years ago.

Lastly, the authors concluded that the initiation dates of the three age classes coincided well with probable flood events based on review of historical meteorological and hydrologic data. This follows the accepted model of cottonwood recruitment being associated with substantial floods.

Conclusions and Recommendations

A preliminary conclusion based on data review and limited field reconnaissance is that the active channel has likely migrated somewhat within the modern floodplain (a 150 to 300-yard-wide swath) in the 150 years since the Massacre, but we did not find any geomorphic evidence that Big Sandy Creek has undergone major channel shifts across the valley since that time. There has been some detailed mapping and age determination of the fluvial terraces; however, no comprehensive map of the fluvial features exists at this time. We suggest the NPS staff consider the following steps in order to amass evidence of where the creek bend may (or may not) have been located in 1864.

- The first level of data collection would be to conduct another field visit with greater detail on where the terrace dating samples were collected and create a map of the terraces in the field (paying particular attention to mapping the terraces in the area around the proposed camp site and the 1864 proposed creek alignment). LIDAR topographic maps would help significantly with mapping the terraces. We completed a preliminary overview of the terraces referenced in the Holmes and Mcfaul report located on the left bank of the creek between the inlet to the Chivington Canal and Dawson Bend and also in the vicinity of the canal breach, downstream. However, we were not able to examine other portions of the valley that may have contained the active channel at an earlier time. We need to examine the north and west sides of the creek and determine the configuration and relative elevation of the terraces, and determine whether the creek channel may have been located within the terrace areas in the 1800's. This could potentially be completed by WRD, GRD (soils scientist), and DSC staff and possibly with the authors of the Holmes and Mcfaul report sometime in FY 2012. The deliverable would be a geomorphic map of Quaternary Deposits (terrace and floodplain) associated with Big Sandy Creek.

- A one-foot LIDAR topographic map could be produced of the entire area in and around the proposed camp site and existing and proposed location of the creek bend. If possible, the map should also cover areas for several miles around the proposed campsite. The map would be useful in locating fluvial terraces as described in the task above. A one-foot topographic map of the area would reveal subtle differences in landscape elevation and might reveal anomalies that suggest anthropogenic influences such as levees and constructed diversion channels, plow lines, buried fence lines, building foundations, and sand pits of historical significance. This evidence could help support or refute the theory that the creek channel bend location was altered by European settlers farming practices or water diversion efforts. Furthermore, a map with this topographic detail could aid park staff in interpreting the history (pre- and post-historic) of this cultural landscape. However, this endeavor would require specialized data management to produce a usable final product.

- As a higher level of investigation, we could pursue absolute age dating of fluvial landforms using a variety of radio-metric techniques. The soil dating project will require contracting specialists that can collect appropriate samples for radiometric dating located across the floodplain or in areas where the channel is suspected to have been in the mid 1800's. Carefully located sample points with absolute dates greater than 150 years would allow us to eliminate portions of the valley as areas where the channel might have existed in the 1800's outside of the modern floodplain. As a caveat, radio-metric age determinations of individual samples can be somewhat costly (several hundred dollars or more) so a comprehensive program could be fairly expensive. Furthermore, absolute age determinations may be highly variable and yield inconclusive or even conflicting results.

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If you have any questions regarding this report please call Mike Martin (970-225-3509) or Kevin Noon at (303) 969-2815.

cc: (by e-mail only)
2380 - Jackson, Tucker, Rosenlieb, Smillie, J. Wagner, Biggam, Parker (file);
BEOL - Fran Pannebaker,
SAND - Karl Zimmermann,
DSC – Darcee Killpack